PARTS OF THE ORIGINAL DOCUMENT

ARE OF POOR REPRODUCTIVE QUALITY

CERTAINES PARTIES DU DOCUMENT ORIGINAL

SONT DE PIÈTRE QUALITÉ DE REPRODUCTION

A REPORT ON 1983 LAKE SUPERIOR WATER QUALITY SURVEILLANCE CRUISES

WATER QUALITY BRANCH

ONTARIO REGION

MAY 1985

TABLE OF CONTENTS

INTRODUCTION

CONCLUSIONS AND RECOMMENDATIONS

RESULTS AND DISCUSSIONS

- SPATIAL AND TEMPORAL VARIATIONS
- DISSOLVED OXYGEN
- NUTRIENTS
  - PHOSPHORUS
  - NITROGEN
  - CHLOROPHYLL, POC AND PON
- CONDUCTIVITY
- DISSOLVED IONS

TABLES

FIGURES

LIST OF TABLES

LIST OF FIGURES

REFERENCES

INTRODUCTION

After the signing of the 1972 Great Lakes Water Quality Agreement, the International Joint Commission (IJC) was requested to carry out a comprehensive study on the pollution problems of Lake Superior, Lake Huron and the St. Marys River. Subsequently, the IJC appointed the Upper Lakes Reference Group to undertake appropriate studies on the Upper Great Lakes. The findings of the Upper Lakes Reference Group were tabled before the IJC in 1976. Among some of its findings on the open waters of Lake Superior were:

1) the overall water quality of Lake Superior and Lake Huron is still excellent, but that man's impact is clearly evident.

2) the overall water quality is much better than the objectives given in water quality agreements and jurisdictional standards, with isolated instances of pollution.

3) atmospheric inputs are significant sources of nutrients, metals and organics.

4) it is imperative that water quality of the Upper Lakes be maintained at their present high quality to preserve and protect existing and future uses.

The renewal of Great Lakes Water Quality Agreement in 1978 again stressed the need for surveillance activities in the open lakes.

The Lake Work Group of the Surveillance Work Group developed and formulated the Great Lakes International Surveillance Plan (GLISP), which detailed sampling strategies and operational plans for the Great Lakes. The purposes of the surveillance plan were : 1) to determine the state of compliance/violations with jurisdictional control requirements and specific objectives of 1978 Great Lakes Water Quality Agreement; 2) to provide information to assist in the design, implementation and assessments of remedial programs; 3) to identify emerging problems; and 4) to identify the need for special studies to improve the understanding of phenomena and /or trends observed as a result of the surveillance program. 1983 had been scheduled for intensive open lake surveillance on Lake Superior. The Department of the Environment (DOE) and the United States Environmental Protection Agency (USEPA) implemented the open lake surveillance plan for Lake Superior. This is a preliminary report on the nutrient and major ion chemistry of Lake Superior.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions drawn from this study are not very different from those of 1973 Lake Superior Intensive Study.

Man's activities continue to impact Lake Superior water quality even though most of the activities seem to originate outside of the Lake Superior Basin.

Water quality in the open waters remains excellent and the lake remains oligotrophic. There are detectable increases in the nitrate, sulphate and major cations in the water of Lake Superior.

Nitrate and sulphate concentrations are increasing at annual rates of 1.1% and 1.2% respectively since 1973.

Cations (calcium, magnesium, potassium, and sodium) have increased by 3%-5% since 1973.

The increases in nitrate and sulphate are likely due to atmospheric deposition.

Atmospheric and tributaries loadings should be monitored to provide reliable loadings so that an assessment can be made to evaulate their impact on water quality.

Phosphorus and conductivity measurements from 1973 appeared to be dubious.

The lack of data in the intervening years makes trend analysis difficult.

The nine year interval of surveillance on Lake Superior, as

recommended by the GLSIP, is too long. It is recommended that Lake Superior be surveyed at a 2-3 year interval.

Except in the western arm of Lake Superior, there is no pronounced spatial or seasonal variation in most of the water quality parameters. For reasons of economy and cost benefit considerations, the number of cruises and sampling locations on Lake Superior could be reduced to one third of its present number.

RESULTS AND DISCUSSIONS

The 1973 intensive study on Lake Superior was inititated largely because of a severe lack of limnological information on the largest and the most pristine of the Laurentian Great Lakes. Apart from gathering information to assess the impact of economic and land use activities on Lake Huron and Lake Superior, the data collected were also meant to become a reference database with which to compare future data. In 1973, six surveillance cruises were conducted by the DOE from May to November, collecting water samples from over 120 stations. The sampling locations and cruise dates are shown in fig. 1. These data represent the largest data set on Lake Superior water quality. Between 1973 and 1983, Lake Superior was surveyed only once in June of 1976 with 66 sampling stations. In 1983, four crusies were carried out by the CSS

LIMNOS from May to October. Sampling locations, sampling methodologies and analytical methods were similar if not identical to those of 1973 (Fig. 2). The purpose of retaining similar sampling locations and sampling protocol were to minimize geographical and analytical variances, and facilitate data comparison with 1973 data.

Analysis of 1973 nutrients and major ions data, summarized by Weiler (1975), showed that the waters of Lake Superior were quite uniform in concentration both vertically and horizontally with small areal variations in the western end of Lake Superior near Duluth. Nutrients such as nitrate and silica had well defined seasonal cycles. Concentrations of major ions had remained constant since the beginning of the century except for nitrate which showed a steady increase of about 3 ug/l per year. A comparison of major ion data collected in Lake Superior and that of atmospheric and tributaries data suggested that there would be a net input of sulphate and chloride from the atmosphere (Thompson 1975).

Table 1 is a statistical summary of the nutrient and major ion data from 1973 and 1983. These statistics are for the whole year and the whole lake with no seasonal or regional breakdown. There are notable differences in the nutrient parameters, nitrate and phosphorus. The inorgacic constituents sulphate and calcium are higher in 1983. These differences are statistically significant

at the 95% level using the standard mean tests.

SPATIAL AND TEMPORAL VARIATIONS

Areal and temporal variations are caused by inflows of tributaries and municipal inputs, the physical circulation of the lake and the temperature and light conditions of the seasons. Lake circulation and its effects on the transport of chloride in Lake Superior had been modelled by Lam (1978). The vertical and horizontal distribution of currents are influenced by the seasonal thermal structure of the lake. A detailed account of the thermal structure and circulation in Lake Superior was described by Bennett (1978). The thermal structure and the physical mixing and tributary inputs have seasonal components while municipal inputs are relatively uniform throughout the year.

Contour plots of conductance, chloride and phosphours (fig 3-5) show consistently higher levels of these variables near populated areas of Lake Superior, and at Duluth Harbor and Thunder Bay. The extent of influence of these inputs were confined to the nearshore waters.

Table 2-5 shows the standard deviations of each parameter by cruise during the year. With the exception of alkalinity, standard deviations were less than 0.5 mg/L for most major ions and less than 0.001 mg/L for nutrients. These levels were at or near the errors of detection of the analytical methods, indicating that the lake was fairly homogeneous with little or no

significant variations.

A more releastic measurement of homogeneity of the water is to examine the coefficient of variation (CV). CVs for most major constituents are less than 5% ; but they are considerably higher in nutrients with 50 to 133%. Such large coefficients of variations are due to the low levels of nutrients which magnified the true extent of the variation.

Theoretically, open lake water quality can be characterized with fewer water samples. Using a conservative standard deviation of 0.005 mg/L from a sample size of 700, the computed confidence interval at 95% confidence level is plus or minus 0.0375 mg/L. By reducing the number of samples to 360, the computed confidence interval would be plus or minus 0.051 mg/L, a level that is still at or near the error of detection of the analytical methods. Therefore, with the exception of Western Superior, the number of open lake sampling stations can be reduced with minimal effects on quantifying open lake water quality.

DISSOLVED OXYGEN

Anoxic hypolimnetic water in Lake Erie has been a matter of grave concern in the late sixties in Lake Erie such that a specific objective of 6.0 mg/L of dissolved oxygen was agreed upon in the 1978 Water Quality Agreement. Dissolved oxygen in Lake Superior averaged 12.77 mg/L, and even under stratified conditions, the minimum dissolved oxygen concentration recorded in 1983 was 8.18

mg/L, well above the objective set forth in the Agreement. With its present trophic level and its great depth, oxygen depletion is not likely to be a problem in Lake Superior.

NUTRIENTS

PHOSPHORUS (TOTAL, TOTAL FILTERED, SOLUBLE REACTIVE PHOSPHORUS)

Phosphorus was measured in three fractions, total phosphorus (TP), a measure of both particulate (organic and inorganic) and dissolved (soluble and colloid); total filtered phosphorus (TFP), phosphorus which passes through a .45 mu filter paper; and soluble reactive phosphorus (SRP), the component of TFP most readily available for biological uptake. Table 6 is a summary of lake wide mean phosphorus concentrations from 1968 to 1983 and Fig 6 is a seasonal plot of total phosphorus. From this figure, it is evident that phosphorus concentrations showed considerable scatter between 0.003 and 0.006 mg/L. However, the annual mean 1983 phosphorus concentration was 0.0035 mg/L, about 40% lower than the 1973 annual mean concentration of 0.0062 mg/L. The other two fractions of phosphorus also showed similar decreases. On the average, total filtered phosphorus declined by 60% and soluble reactive phosphorus by 62%. Elsewhere downstream from Lake Superior, the mean phosphorus concentration in Lake Huron was .0046 mg/L (1980) and 0.0042 mg/L in Georgian Bay. There was no significant change in phosphorus concentration in Lake Huron

since 1971. (Stevens et al 1983). In Lake Erie, and Lake Ontario, there were significant declines in TP concentrations. 1978 TP concentration in the surface waters of the Western basin of Lake Erie was .019 mg/L, almost half the recorded value of .045 mg/l in 1970 (Rathke & Edwards 1984). In Lake Ontario, total phosphorus gradually decreased from .025 to .014 mg/L from 1970 to 1980 (IJC 1983). Therefore, it seems that phosphorus levels in the Lower Great Lakes and the Upper Lakes demonstrate differing trends.

In a lake the size of Lake Superior, a change of this magnitude is inconceivable. Indeed, it is difficult to postulate any mechanisms which could account for a decline in phosphorus. In the Lower Lakes, the decrease in phosphorus could be attributed to a reduction of phosphorus load from municipal sources and sedimentation. But in Lake Superior, sedimentation rate is low (Thomas 1978) and municipal inputs are fractions of the estimated total load (IJC 1977). Even with a huge reduction in phosphorus load, with a flushing time of 117 years, the effect would not have any impacts for decades. The only logical explaination left is an analytical one. Although stringent quality control in the laboratory is enforced to ensure the precison and the accuracy of the analytical methods within a batch of samples or a year of operation, the accuracies of two sets of results, ten years apart, may not be comparable at such low levels. Phosphorus data from Lake Huron in 1971 showed a mean level of 0.0041 mg/L, a value lower than the 1973 Lake Superior data but closer to the

1983 data. Thus it would appear that past phosphorus data on Lake Superior were biased high. With no data in the intervening years, it is not possible to make any valid assessment on the accuracies of the two data sets. The nine year interval of surveillance on the Upper Lakes is too long if an assessment is to be made on the changes in water quality. It is only reasonable to assume that without other supporting evidence, the change in phosphorus may not be a valid one. Despite this uncertainty, at its present phosphorus concentration of 0.004 mg/L, Lake Superior is considered to be oligotrophic (Dobson 1974).

NITROGEN (nitrate + nitrite, kjeldahl and ammonia)

Four forms of nitrogen were measured; nitrate + nitrite, ammonia, kjeldahl nitrogen and total particulate nitrogen. Among the four, nitrate + nitrite and ammonia are readily available for phytophankton assimulation and thus they usually exhibit a seasonal minimum during the growing season. Fig 7 is a seasonal plot of Lake Superior's nitrate concentration. The seasonal variation is not as evident in 1983 as in 1973 due to the smaller number of cruises. Contour plots of nitrate + nitrite (fig 8) showed that elevated levels of nitrate +nitrite occurred in warmer nearshore waters where nutrient inputs were. Overall, mean annual nitrate concentration in 1983 was 0.321 mg/L compared to a mean concentration of 0.286 mg/L in 1973, an increase of about 0.035 mg/L over the ten year period. This increase of about

0.003 mg/l per year is consistent with an observation made by Weiler (1978) who suggested a steady annual rate of increase in nitrate of 0.003 mg/L in Superior since 1900. Unlike the case with phosphorus, similar increases in nitrate have also been observed in the other Great Lakes, with increasing rates going down the Great Lakes. The annual rate of increase for nitrate in Georgian Bay was about .0045 mg/L and .0054 mg/L for Lake Huron (IJC 1983). Average nitrate concentrations in Lake Erie were also noted to be on the rise at a rate of 0.0094 mg/L/yr (Rathke and Edwards 1984). In Lake Ontario, nitrate has been steadily increasing by about .0088 mg/l since 1969 (IJC 1983). Reasons for these were not known although atmospheric inputs and higher runoffs have been speculated to be the reasons. A separate study (Chan 1984) estimated that atmospheric nitrogen accounted for over 54% of the total inputs into Lake Superior.

(Kjeldahl nitrogen + ammonia) measures of total organic nitrogen, and reflects both dynamics of plankton growth and organic pollution. Lake wide mean kjeldahl nitrogen was 0.083 mg/L and it areal distribution resembled that of total phosphorus. Mean annual ammonia concentration was 0.003 mg/L, only a fraction of kjeldahl nitrogen. Over half of the ammonia values were below the detection limit.

CHLOROPHYLL, PARTICULATE NITROGEN AND CARBON

Chlorophyll a, although not a direct measurement of biomass, is

often used as an indicator of productivity. Other biomass indicators are particulate organic nitrogen and carbon. These were measured from integrated water samples over a depth of 50 M. Mean chlorophyll concentration for 1983 showed little change from 1973 measurement. Vollenweider (1974) and Munawar (1978) classified Lake Superior as an extremely oligotrophic environment based on chlorophyll data and algal biomass species composition. The cold temperate climate and the low nutrient levels are probably the limiting factors in deciding the trophic state of Lake Superior.

CONDUCTIVITY

Conductivity in fresh water is a function of dissolved salts content and their ionic strength. An increase of specific conductance is usually associated with an increase of salt content. Fig. 10 is a plot of conductance data from 1968 to 1983. The 1973 data were substantially lower than the other years which lie between 98 uS and 106 uS. In addition, the 1973 data showed a gradual decline from spring to fall. This behaviour is unusual for conductivity which normally does not exhibit any pronounced seasonal variation unless there is a seasonal influx of or changes in major ions. If the 1973 conductivity data were doubtful, and the 1971 and 1972 data are taken to be correct, then the increase in conductivity would be about 5 uS.

Although there is no specific objective for conductivity in the

1978 Water Quality Agreement, conductivity has been used as a substitute measurement for total dissolved solids (TDS) which has a specific objective of 200 mg/l for the lower Great lakes in the 1978 Water Quality Agreement. Using the conversion factor of 0.62, Lake Superior would have a TDS of 62 mg/l. The TDS objective should not be applicable to Lake Superior. A TDS objective for the Upper Lakes should be one of non-degradation.

MAJOR IONS (CA, MG, K, NA) and ALKALINITY

Lake Superior is a head water lake, receiving most of its water and minerals from its tributaries and the atmosphere. Chemical weathering is the principal source of dissolved minerals to Lake Superior. In the absence of any significant human influence, dissolved minerals in its water should be in a steady state of equilibrium with its drainage basins with output balanced by its input. This assumption is supported by the fact that major ion concentrations have not changed since 1885.

Basically, Lake Superior is calcium-magnesium-carbonate water. Calcium is about three times magnesium and the sum of calcium and magnesium is approximately equal to carbonate. The average major ion concentrations in 1973 and 1983 are given in table 3. There are noticeable changes in calcium, magnesium, chloride, sulphate and alkalinity. However, on balance, the calcium-magnesium-carbonate characteristic is preserved. Both sets of data are charged balanced, indicating that there are no

discrepencies in the analysis.

Major ions loading to lake Superior was examined in detail by Thompson (1976) who concluded that chemical weathering in the Lake Superior basin is the principal source of calcium and magnesium to the lake, while the atmosphere is the major source of sulphate and chloride, and that there was an excess of chloride and sulphate loadings from the atmosphere. Furthermore, the expected increases in concentration would not be detectable for decades.

Figures from table 7 showed that over the ten year period, calcium and magnesium had a 3% increase while chloride and sulphate had a 12% increase. This suggests different sources for the cations and the anions, confirming the observations made by Thompson (1976). However, the rate of change is faster than predicted.

Changes in alkalinity are asscciated with neutralization of acidic and carbonate ions. Acidification of many lakes in North America have been attributed to acidic precipitation. The average pH of Lake Superior rainfall is 4.5 . Lake Superior is not susceptible to acidic precipitation mainly because of direct rainfall only accounts for .8% of its water volume budget. The measured 1% decrease of alkalinity is probably not significant.

REFERENCES

Bennett, E.B. 1978. Lake Superior Thermal Regime. Internat. Assoc. Great Lakdes Res. 4(3-4):310.

Chan, C.H. and Perkins, L.H. 1984 Lake Superior Wet Deposition 1983. Unpublished report, WQB/IWD.

Dobson, H.F. 1974. A Summary and Comparison of Nutrients and Related Water Quality in Lake Erie, Ontario, Huron, and Superior. J. Fish. Res. Bd. Canada 31(5):731-738.

International Joint Commission 1977. The Waters of Lake Huron and Lake Superior. Upper Lakes Reference Group. vol 3.

International Joint Commission 1978. Canada and the United States Great Lakes Water Quality Agreement of 1978.

International Joint Commission 1979. Great Lakes International Surveillance Plan, Part A and Part B.

International Joint Commission 1983. Report on Great Lakes Water Quality, Appendix A, Great Lakes Surveillance.

Lam, D.C. 1978. Simulation of Water Circulations and Chloride Transports in Lake Superior for summer 1973. Internat. Assoc.

Great Lakes Res. 4(3-4):343.

Ratheke, D. E. and Edwards, C. J., 1984. Synposis of Lake Erie Water Quality, Report to the Surveillance Work Group, International Joint Commission.

Stevens, R. J. J., Neilson, M. A. T., and Warry, N. D. 1983. Water Quality of the Lake Huron-Georgian Bay System. Internal report, Water Quality Branch, Environment Canada.

Thompson, M. E. 1978. Major Ions Loadings to Lake Superior. Internat. Assoc. Great Lakes Res. 4(3-4):367.

Vollenweider, R. A., Munawar, M., and Stadelmann, P. 1974. A Comparative Review of Phytoplankton and Primary Production in the Laurentian Great Lakes. J. Fish. Res. Bd. Canada 31(5):739-762.

Weiler, R.R. 1978. Chemistry of Lake Superior, Internat. Assoc. Great Lakes Res. 4(3-4):370

TABLE 1.

STATISTICAL SUMMARY OF NUTRIENTS AND MAJOR IONS IN LAKE SUPERIOR 1973 AND 1983

	1973				1983				
	MEAN	N	STD.DEV.	RANGE	MEAN	N	STD. DEV.	RANGE	%
CONDUCTANCE	92.38	898	6.673	58.0-142.0	103.14	2311	6.900	49.0-164.0	40.610
DISS.OXYGEN	12.77	776	0.675	9.15-14.02	13.00	441	0.848	8.18-14.89	-4.495
ALKALINITY	41.95	3273	1.33	28.9-49.9	41.44	2115	2.91	1.00-54.1	-7.562
DISS.ORG.CARBON	2.93	938	1.467	0.4-20.0	1.10	2115	0.992	1.0-30.4	-23.566
TOT.PHOS.	0.0062	2796	0.0036	.0009-.0510	0.0035	2133	0.0026	.0003-.0975	-30.562
SOL.R.PHOS.	0.0015	3867	0.0014	.0001-.0297	0.0006	2131	0.0004	.0002-.0112	-37.614
TOT.FIL.PHOS.	0.0043	2575	0.0022	.0006-.0240	0.0018	2129	0.0007	.0004-.0144	-55.289
AMMONIA	0.006	3870	0.0051	.000-.150	0.002	2133	0.0020	.000-.069	-42.45
NITRATE	0.283	3886	0.028	.197-.639	0.321	2133	0.021	.225-.336	58.157
SULPHATE	3.01	698	0.368	1.20-7.20	3.44	2126	0.216	2.90-6.00	28.941
CHLORIDE	1.18	2269	0.217	0.60-6.30	1.32	2131	0.190	0.90-4.40	23.011
SILICATE	2.41	3890	0.144	1.27-4.67	2.32	2131	0.134	1.57-3.13	-23.75
CALCIUM	12.92	699	0.531	10.9-18.2	13.35	1589	0.494	0.10-16.7	17.48
MAGNESIUM	2.66	699	0.114	2.4-3.4	2.74	1589	0.095	0.10-3.30	16.069
POTASSIUM	0.48	699	0.134	0.2-4.0	0.50	1589	0.024	0.00-0.90	-68.916
SODIUM	1.26	699	0.182	1.1-1.8	1.30	1589	0.120	0.00-3.00	-5.322

TABLE 2. MAY CRUSIE DESCRIPTIVE STATISTICS

VARIABLE	UNITS	N	MEAN	MIN	MAX	STD.DEV	COE. VAR.
TEMP.	C	476	3.15	1.78	8.07	1.07	33.97
CONDUCTANCE	uSIE	475	106	99	119	2	1.89
DISS.OXYGEN	MG/L	472	13.51	11.84	15.25	0.45	3.33
OXYGEN SATN.	%	472	103.0	89.0	116.0	4.0	3.88
pH		475	7.93	7.09	8.82	0.10	1.26
ALKALINITY	MG/L	473	40.7	1.0	47.4	2.4	5.90
TKN	MG/L	474	0.091	0.061	2.09	0.017	18.68
T.PHOS	MG/L	474	0.0031	0.0016	0.0179	0.0014	45.16
SR P	MG/L	470	0.0006	0.0002	0.0017	0.0003	50.00
TF P	MG/L	474	0.0017	0.0006	0.0007	0.0006	35.27
AMMONIA	MG/L	472	0.002	0.001	0.007	0.0001	5.00
NO3+NO2	MG/L	474	0.334	0.225	0.354	0.01	2.99
SO4	MG/L	470	3.4	3	4.5	0.2	5.88
CL	MG/L	473	1.3	1.2	2.4	0.2	15.38
SILICATE	MG/L	473	2.39	1.57	2.92	0.12	5.16
CALCIUM	MG/L	476	13.4	4.8	16.7	0.5	3.73
MAGNESIUM	MG/L	473	2.8	2.5	3.2	0.1	3.57
POTASSIUM	MG/L	473	0.5	0.5	0.6	0	0.00
SODIUM	MG/L	473	1.3	1.2	2	0.1	7.69
CHLOROPHYLL	MG/L	112	1.2	0.7	4.1	0.4	33.33
IPOC	MG/L	112	0.137	0.077	0.562	0.066	48.18
I-N TP	MG/L	112	0.017	0.009	0.042	0.006	35.29

TABLE 3. JUNE CRUSIE DESCRIPTIVE STATISTICS

VARIABLE	UNITS	N	MEAN	MIN	MAX	STD.DEV	COE. VAR
TEMP.	C	543	5.39	3.06	15.4	2.78	51.58
CONDUCTANCE	uSIE	543	99.0	89.0	126.0	3.0	3.03
DISS.OXYGEN	MG/L	539	13.16	10.68	15.01	0.79	6.00
OXYGEN SATN.%		539	106.0	41.0	128.0	5.0	4.72
pH		543	7.93	7.43	8.97	0.10	1.25
ALKALINITY	MG/L	543	41.2	31.7	53.1	1.6	3.88
TKN	MG/L	521	0.087	0.052	0.196	0.018	20.67
T.PHOS	MG/L	543	0.0034	0.0003	0.0133	0.0013	38.24
SR P	MG/L	543	0.0006	0.0002	0.0038	0.0003	50.00
TF P	MG/L	543	0.002	0.0007	0.0117	0.0007	35.00
AMMONIA	MG/L	543	0.003	0.001	0.016	0.002	66.67
NO3+NO2	MG/L	543	0.328	0.236	0.35	0.013	3.96
SO4	MG/L	543	3.5	3.1	6	0.3	8.57
CL	MG/L	543	1.3	1.0	2.4	0.1	7.69
SILICATE	MG/L	543	2.388	2.25	3.13	0.065	2.72
CALCIUM	MG/L	ND	ND	ND	ND	ND	ND
MAGNESIUM	MG/L	ND	ND	ND	ND	ND	ND
POTASSIUM	MG/L	ND	ND	ND	ND	ND	ND
SODIUM	MG/L	ND	ND	ND	ND	ND	ND
CHLOROPHYLL	MG/L	112	1.1	0.6	4.7	0.4	36.36
IPOC	MG/L	112	0.168	0.08	0.5	0.054	32.14
I N IF	MG/L	112	0.019	0.01	0.05	0.007	36.84

TABLE 4. SEPTEMBER CRUSIE DESCRIPTIVE STATISTICS

VARIABLE	UNITS	N	MEAN	MIN	MAX	STD.DEV	COE.VAR.
TEMP.	C	604	10.00	3.56	21.21	6.44	64.40
CONDUCTANCE	uSIE	589	107.0	49.0	164.0	8.0	7.48
DISS.OXYGEN	MG/L	602	11.82	8.10	14.89	1.66	14.04
OXYGEN SATN.	%	602	105.0	90.0	133.0	6.0	5.71
pH		599	7.98	7.53	8.51	0.22	2.76
ALKALINITY	MG/L	589	41.1	25.9	54.1	2.7	6.57
TKN	MG/L	605	0.083	0.024	0.303	0.02	24.10
T.PHOS	MG/L	605	0.0036	0.0014	0.0181	0.0013	36.11
SR P	MG/L	599	0.0007	0.0002	0.0112	0.0005	71.43
TT P	MG/L	601	0.0021	0.001	0.0144	0.0007	33.33
AMMONIA	MG/L	602	0.003	0.001	0.069	0.004	133.33
NO3+NO2	MG/L	605	0.317	0.248	0.366	0.026	8.20
SO4	MG/L	605	3.5	3.1	4.4	0.2	5.71
CL	MG/L	605	1.3	0.9	4.4	0.2	15.38
SILICATE	MG/L	605	2.188	1.95	2.55	0.121	5.53
CALCIUM	MG/L	605	13.3	12.7	14.5	0.2	1.50
MAGNESIUM	MG/L	605	2.8	2.5	3.1	0.1	3.57
POTASSIUM	MG/L	473	0.5	0.5	0.6	0	0.00
SODIUM	MG/L	473	1.3	1.2	2	0.1	7.69
CHLOROPHYLL	MG/L	112	1.2	0.7	4.1	0.4	33.33
IPOC	MG/L	112	0.137	0.077	0.562	0.066	48.18
I-N TP	MG/L	112	0.017	0.009	0.042	0.006	35.29

TABLE 5. OCTOBER CRUISE DESCRIPTIVE STATISTICS

VARIABLE	UNITS	N	MEAN	MIN	MAX	STD.DEV	COE. VAR.
TEMP.	C	511	7.02	2.90	13.18	2.68	38.18
CONDUCTANCE	uSIE	511	105.0	87.0	117.0	4.0	3.81
DISS.OXYGEN	MG/L	509	12.13	9.35	14.77	0.92	7.58
OXYGEN SATN.	%	509	101.0	82.0	116.0	3.0	2.97
pH		510	7.84	7.49	8.14	0.11	1.40
ALKALINITY	MG/L	509	42.6	1.8	47.6	3.7	8.69
TKN	MG/L	511	0.077	0.048	0.193	0.017	22.08
T.PHOS	MG/L	511	0.0036	0.0016	0.0975	0.0048	133.33
SR P	MG/L	509	0.0007	0.0003	0.0050	0.0003	42.86
IF P	MG/L	511	0.0016	0.0004	0.0064	0.0007	43.75
AMMONIA	MG/L	511	0.004	0.001	0.015	0.003	75.00
NO3+NO2	MG/L	511	0.308	0.267	0.356	0.018	5.84
SO4	MG/L	510	3.4	2.9	4.5	0.2	5.88
CL	MG/L	510	1.3	1.0	3.3	0.2	15.38
SILICATE	MG/L	510	2.34	2.17	2.71	0.121	5.17
CALCIUM	MG/L	510	13.3	12.3	16.3	0.3	2.26
MAGNESIUM	MG/L	510	2.7	2.6	3.1	0.1	3.70
POTASSIUM	MG/L	510	0.5	0.3	0.7	0.0	0.00
SODIUM	MG/L	510	1.3	1.2	2.6	0.1	7.69
CHLOROPHYLL	MG/L	107	1	0.4	2.7	0.4	40.00
IPOC	MG/L	107	0.143	0.087	0.258	0.036	25.17
I-N TP	MG/L	107	0.023	0.012	0.070	0.010	43.48

TABLE 6. LAKE SUPERIOR TOTAL PHOSPHORUS 1968-1983

YR-MO	MEAN	N	STD.DEV.	MINIMUM	MAXIMUM	COE.VAR.
68-08	0.0062	60	0.0067	0.0007	0.0424	108.06
70-04	0.0044	55	0.0011	0.0023	0.0088	25.00
70-10	0.0044	57	0.0072	0.0013	0.4240	163.64
71-05	0.0045	335	0.0142	0.0016	0.2249	315.56
71-07	0.0040	334	0.0031	0.0007	0.0303	77.50
71-10	0.0028	416	0.0013	0.0007	0.1270	46.43
73-05	0.0083	452	0.0004	0.0027	0.0346	4.94
73-06	0.0054	516	0.0025	0.0020	0.0230	46.30
73-07	0.0049	524	0.0017	0.0024	0.0168	34.69
73-09	0.0077	460	0.0036	0.0010	0.0361	46.75
73-10	0.0052	380	0.0021	0.0022	0.0217	40.38
73-11	0.0055	459	0.0034	0.0009	0.0360	61.82
76-06	0.0050	202	0.0021	0.0029	0.1620	42.00
83-05	0.0031	474	0.0014	0.0016	0.0179	45.16
83-06	0.0034	543	0.0013	0.0003	0.0133	38.24
83-09	0.0036	605	0.0013	0.0014	0.0181	36.11
83-10	0.0036	511	0.0048	0.0016	0.0975	133.33

TABLE 7. MAJOR IONS IN LAKE SUPERIOR

	1973		1983		DIFFERENCE	
	mg/l	meq/l	mg/l	meq/l	mg/l	%
CALCIUM	12.92	0.64	13.35	0.67	0.43	3.33
MAGNESIUM	2.66	0.22	2.74	0.23	0.08	3.01
POTASSIUM	0.48	0.01	0.5	0.01	0.02	4.17
SODIUM	1.26	0.05	1.3	0.05	0.04	3.17
CATIONS	17.32	0.92	17.89	0.96		
CHLORIDE	1.18	0.03	1.32	0.04	0.14	11.86
SULPHATE	3.01	0.06	3.44	0.07	0.43	14.29
NITRATE	0.28	0.02	0.32	0.02	0.04	14.29
ALKALINITY	42.01	0.84	41.44	0.82	-0.57	-1.36
ANIONS	46.48	0.93	46.52	0.95		

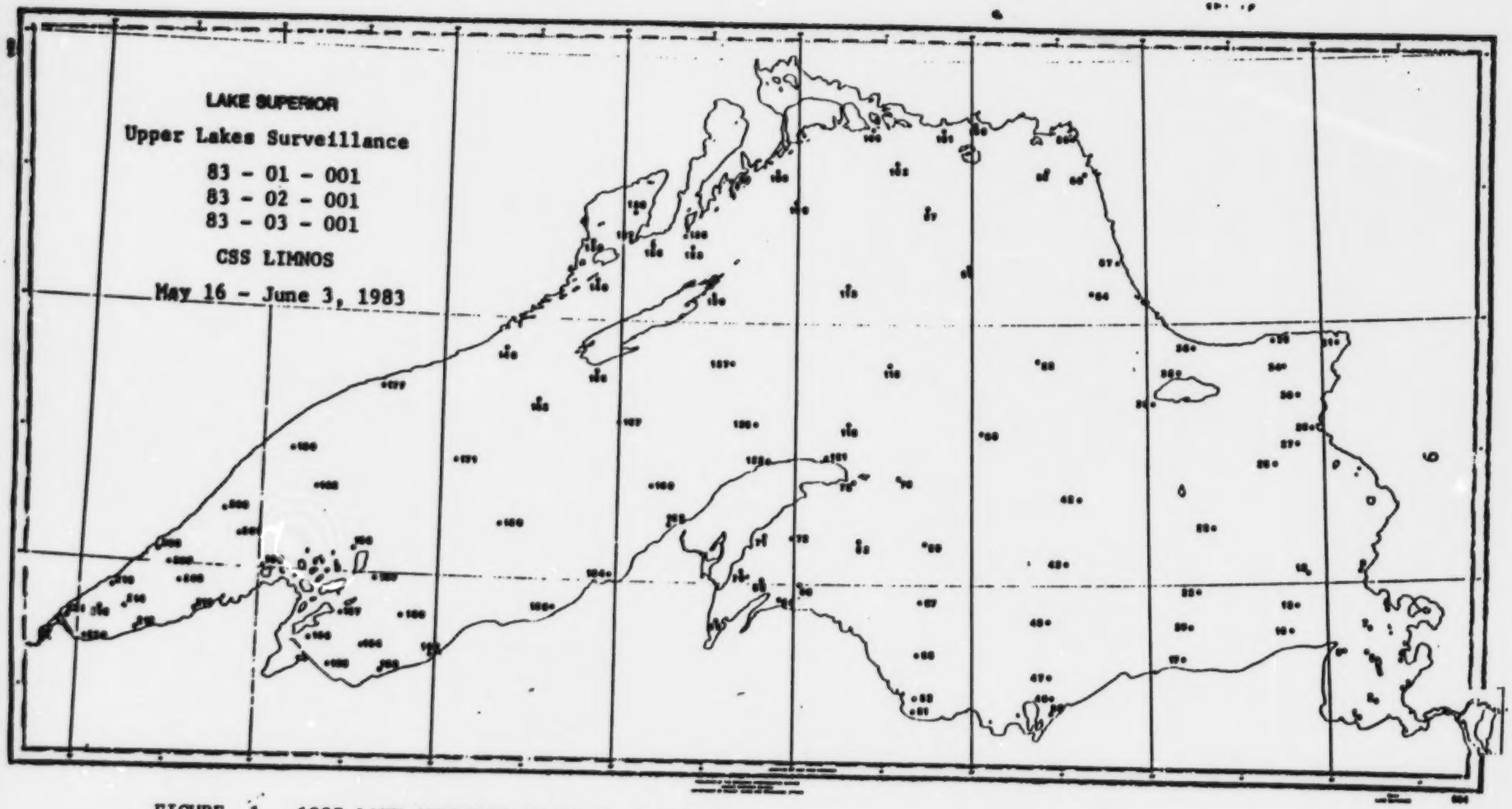


FIGURE 1. 1983 LAKE SUPERIOR SAMPLING LOCATIONS

M. MARTIN KARLSEN
..ack Plot
Monitor - Lake Superior
73 - 03 - 101

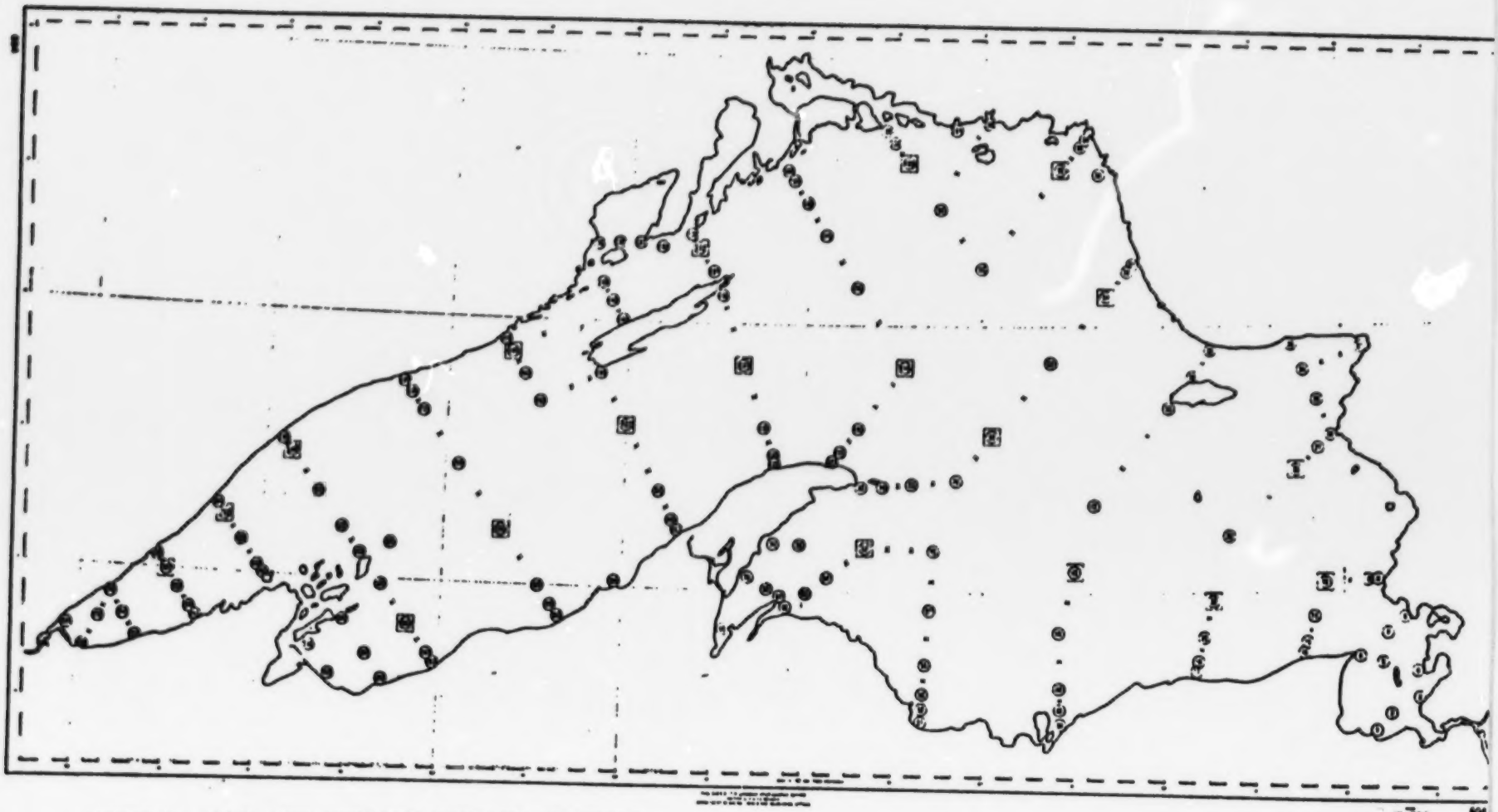


FIGURE 2. 1973 LAKE SUPERIOR SAMPLING LOCATIONS

FIGURE 3. DISTRIBUTION OF TOTAL PHOSPHORUS IN LAKE SUPERIOR 1983

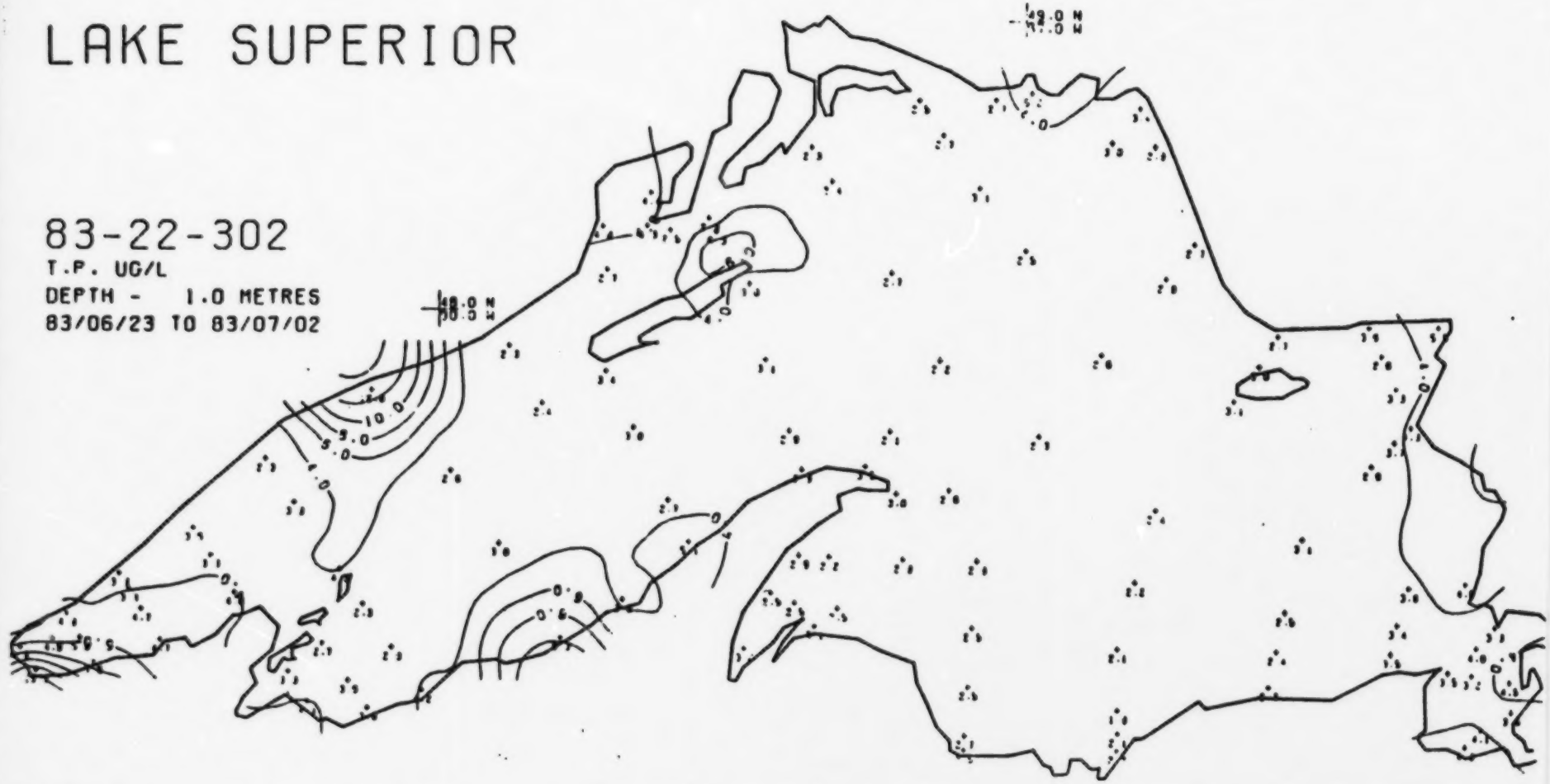


FIGURE 4. DISTRIBUTION OF CONDUCTANCE IN LAKE SUPERIOR 1983

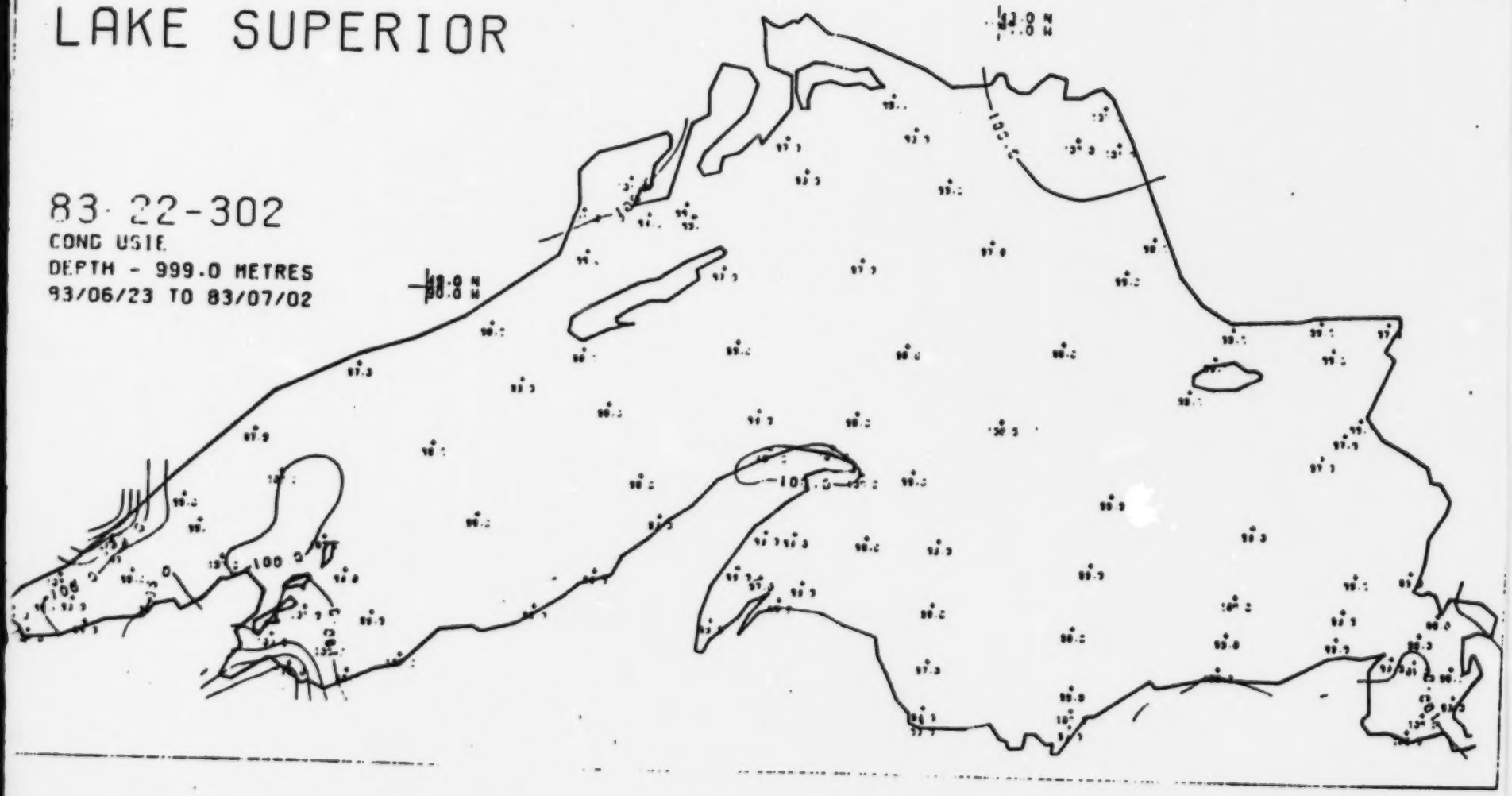
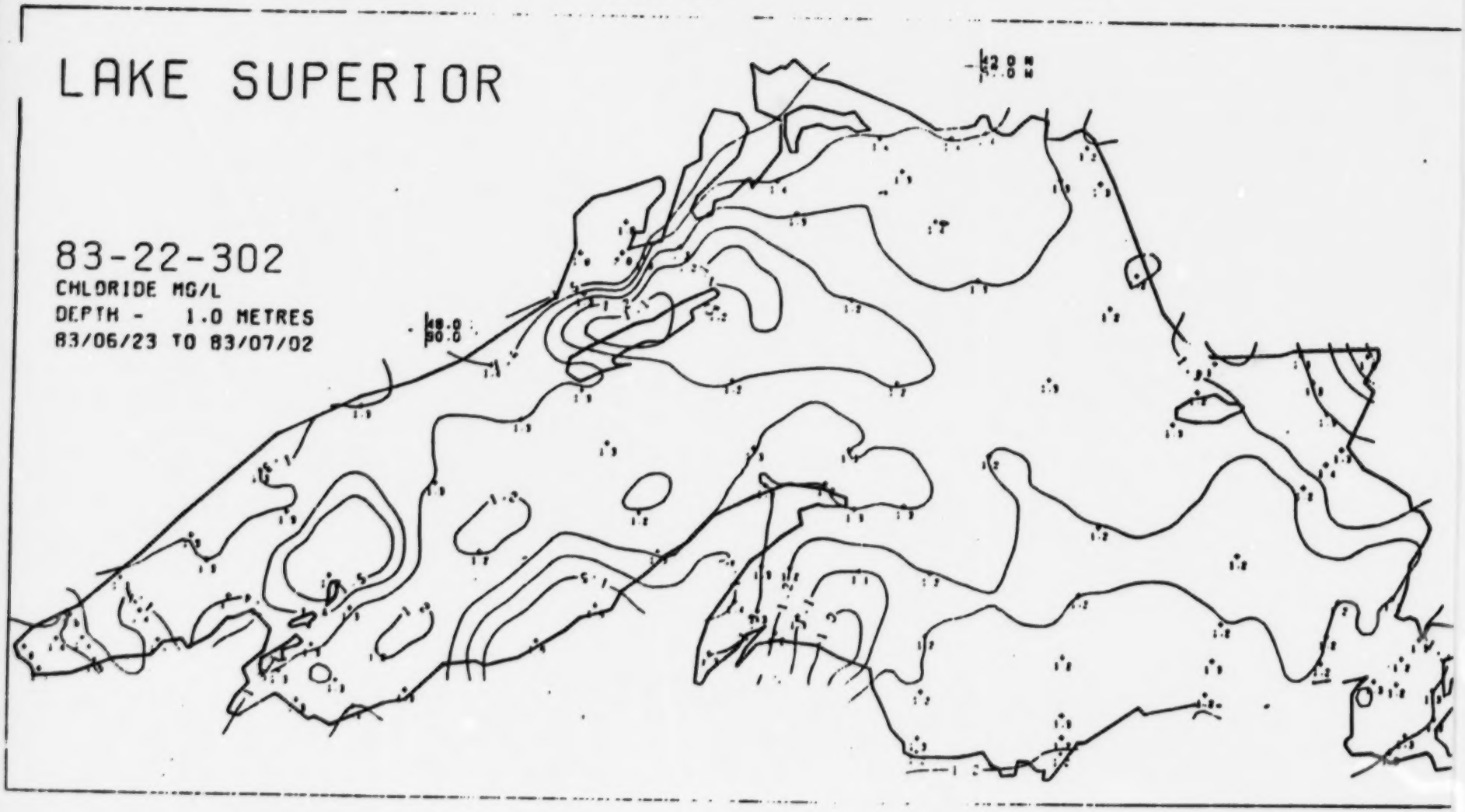


FIGURE 5. DISTRIBUTION OF CHLORIDE IN LAKE SUPERIOR 1983



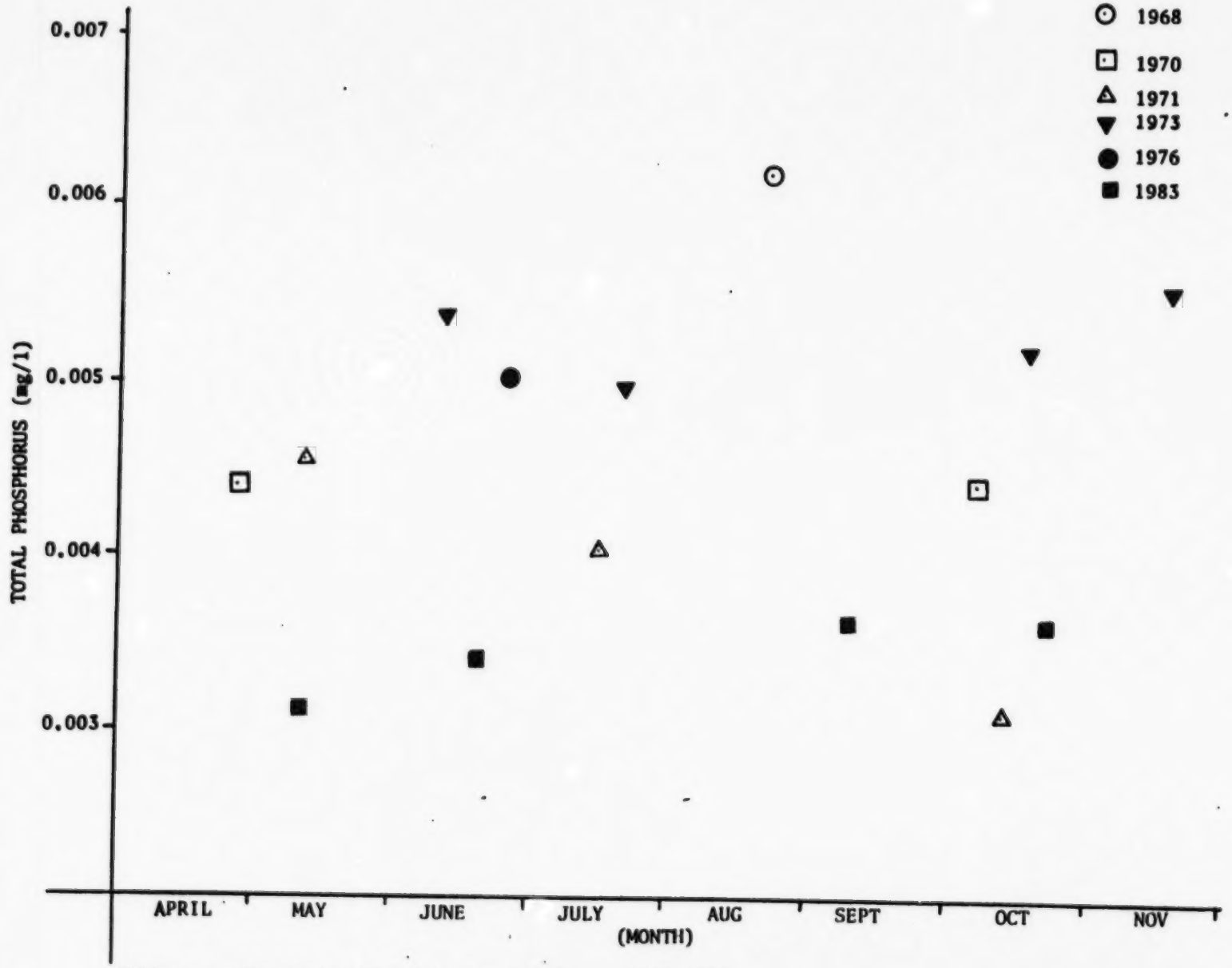


FIGURE 6. Seasonal plot of total phosphorus 1968-1983.

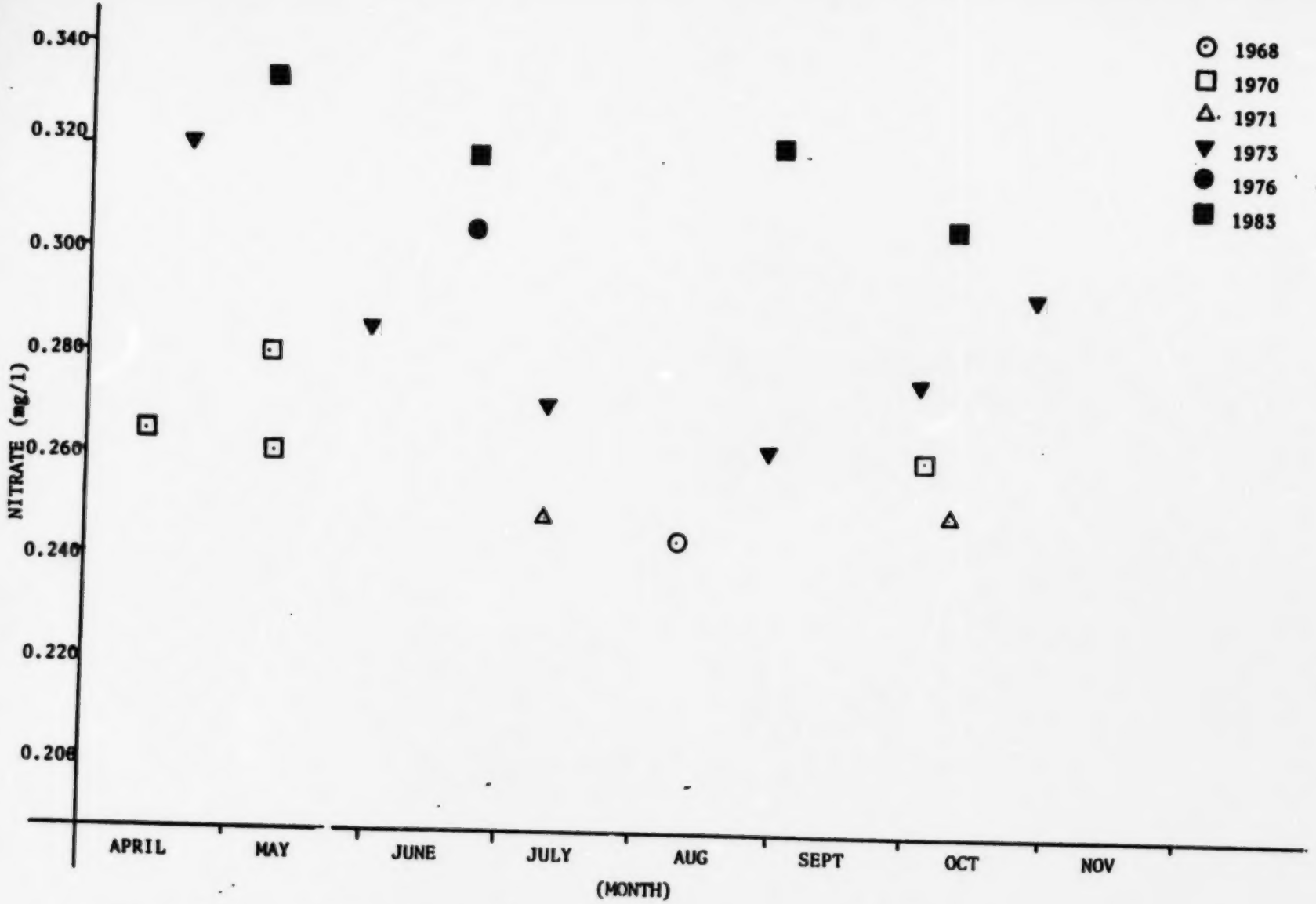
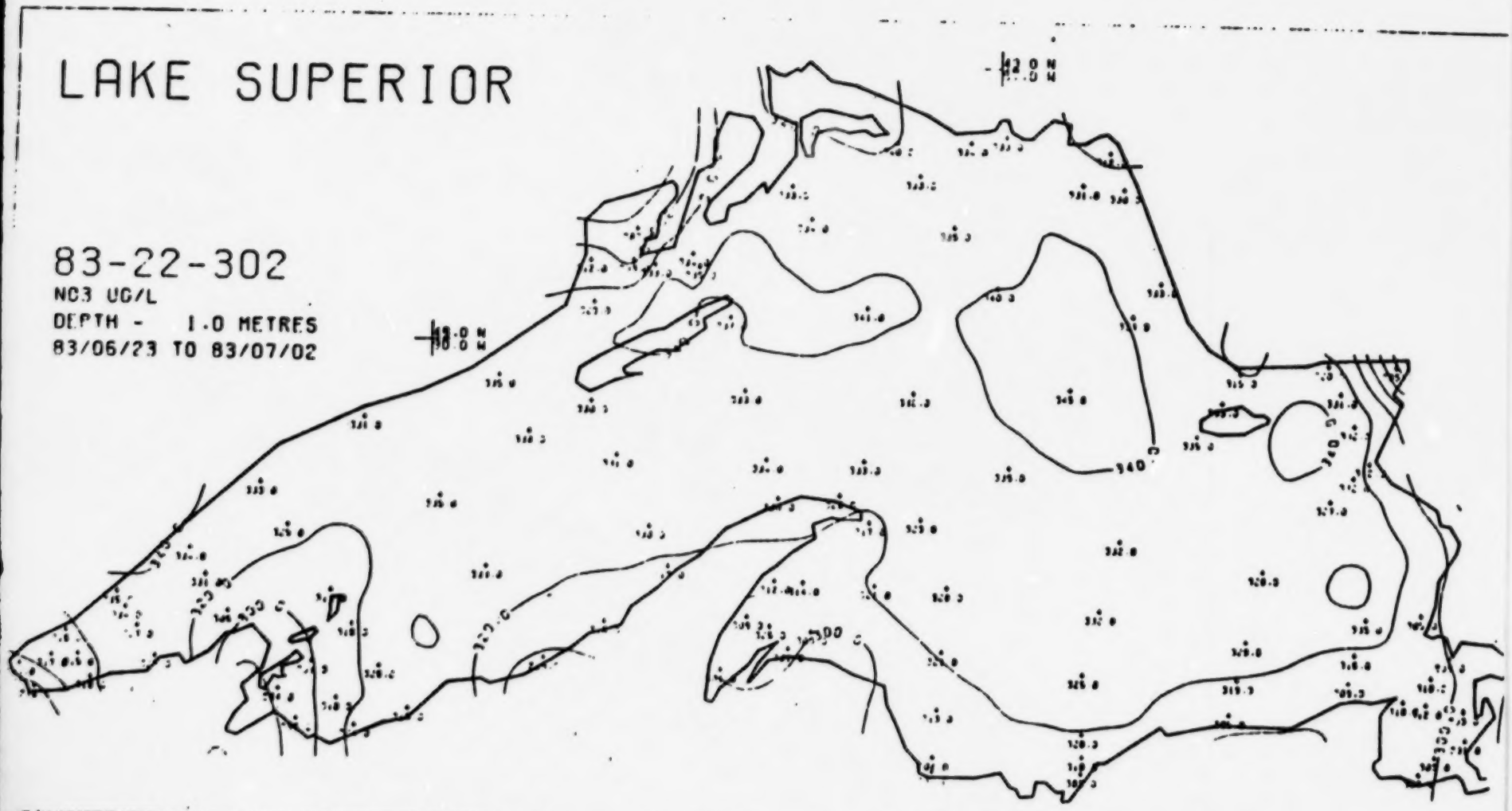


FIGURE 7. Seasonal plot of nitrate 1968-1983.

FIGURE 8. DISTRIBUTION OF NITRATE + NITRITE IN LAKE SUPERIOR 1983



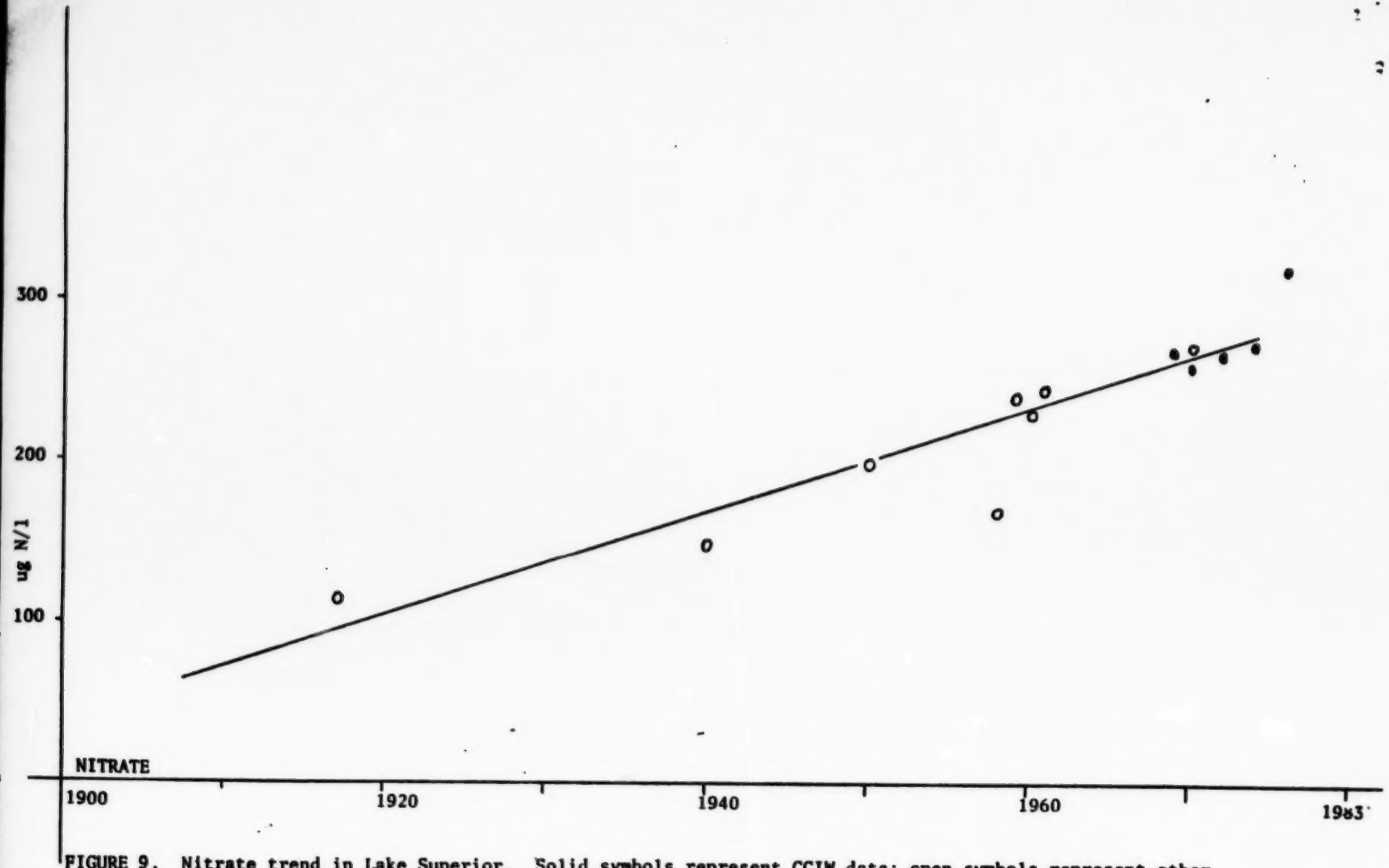


FIGURE 9. Nitrate trend in Lake Superior. Solid symbols represent CCIW data; open symbols represent other data. The trend line has been fitted bye eye (Weiler 1978).

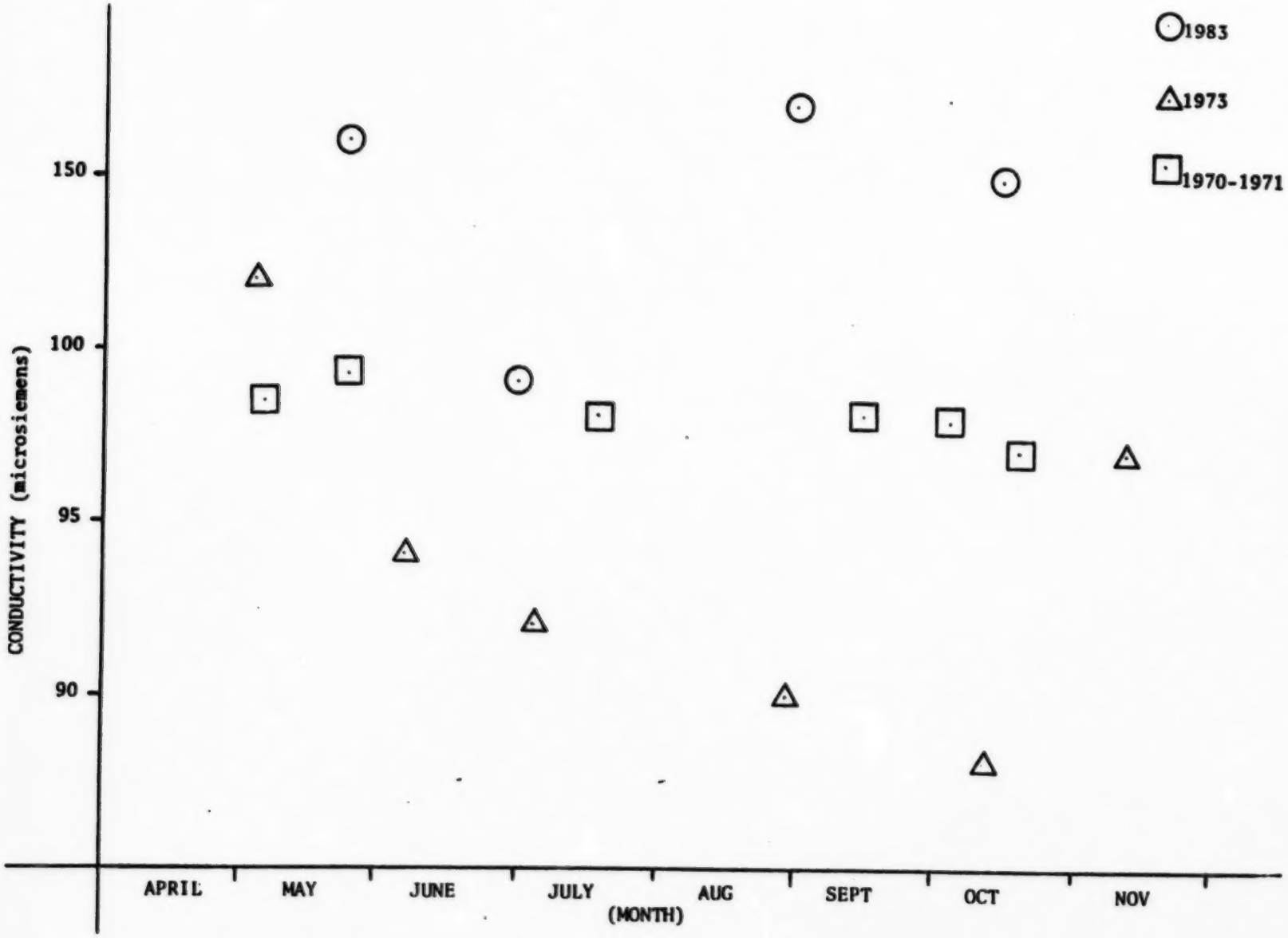


FIGURE 10 LAKE SUPERIOR CONDUCTIVITY 1970-1983

LIST OF FIGURES

Fig. 1 1983 Lake Superior Sampling Locations

Fig. 2 1973 Lake Superior Sampling Locations

Fig. 3 Distribution of total phosphorus in Lake Superior 1983

Fig. 4 Distribution of conductance in Lake Superior 1983

Fig. 5 Distribution of chloride in Lake Superior 1983

Fig. 6 Seasonal plot of total phosphorus 1968-1983

Fig. 7 Seasonal plot of Nitrate

Fig. 8 Distrubution of Nitrate + Nitrite in Lake Superior 1983

Fig. 9 Nitrate Trend in Lake Superior

Fig 10 Seasonal plot of Conductance 1968-1983

LIST OF TABLES

Table 1 Statistical summary of nutrients and major ions 1973 & 1983

Table 2 Lake Superior Cruise Statistics May 1983

Table 3 Lake Superior Cruise Statistics June 1983

Table 4 Lake Superior Cruise Statistics Aug 1983

Table 5 Lake Superior Cruise Statistics Oct 1983

Table 6 Statistical summary of total Phosphorus 1968 1983

Table 7 Major ions in Lake Superior 1973 and 1983